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SUPPLEMENTARY REPORT

PROPELLANT
SURVEILLANCE REPORT
ANB-3066 PROPELLANT

SUPPLEMENT TO MAKPH REPORT NR 450(80)

PROPELLANT ANALYSIS LABORATORY SECTION
HILL AIR FORCE BASE, UTAH 84056

MANPA REPORT NR 453(80)

13 April 1981

Industrial Products & Ldg Gear Division
Directorate of Maintenance
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Hill Air Force Base, Utah 84056

MINUTEMAN III CASEBOND ANALYSIS OF CARTON DATA FROM CONSTANT LOAD SHEAR AND CONSTANT LOAD TENSILE TESTING

Propellant Analysis Laboratory Section

13 April 1981

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Partial

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MINUTEMAN III CASEBOND AGING ANALYSIS
SUPPLEMENT TO MAKPH REPORT NR 450(80)

1. This report is a supplement to MAKPH report NR 450(80), "Propellant Surveillance Report ANB-3066 Propellant", dated December 1980.

2. Previously prepared lined cartons were cast at the same time their representative field motors were cast. These cartons enable the machining of casebond specimens for constant load shear and constant load tensile testing. The specimens were designed to test the liner bond strength of ANB-3066/SD-851-2 liner/V45 rubber. A carton sampling usually consists of 11 or 12 specimens. Shear and tensile samplings are never from the same carton. Shear specimens, 0.2 inches thick by two inches in diameter, are bonded to aluminum. Tensile specimens are two inches in diameter with a filet that reduces the propellant/liner/insulation interface to 1.5 inches in diameter. The propellant at this interface is bonded into a pipe section and the rubber insulation is bonded to aluminum.

3. A constant load test frame having attached shear or tensile holding fixtures is used to test casebond specimens. The test specimens are placed on the holding fixtures and weights to exert a constant stress are attached below them. For each carton sampling, different weights are attached to the individual specimens with the intent to cause failure over a range of one to 100 minutes. In general, the 11 or 12 specimens in each carton sampling are divided into four groups and the two or three specimens within each group are each subjected to the same amount of stress.

4. For each carton sampling, the times to rupture and their corresponding stresses were subjected to regression analysis. The one minute and 100 minute stress values were then calculated from these regression analyses. The results are given in Tables 1 to 4. Also, the data from these analyses are classified according to the polymer used in the manufacture of propellant in the cartons tested. The polymers are: G for General Tire and Rubber and P for Phillips. These two polymer groups were tested over three test periods, test phases B, C and D.

5. One minute and 100 minute data from the carton sampling regressions, Tables 1 to 4, were subjected to aging analysis, i.e., stress regressed against age. The data selected for aging analysis excluded data from carton sampling regressions that had correlation coefficients less than the absolute value of 0.9, see again Tables 1 to 4. Where sufficient one minute and 100 minute data existed, an aging analysis regression was made for each polymer and test phase combination. Table 5 indicates the aging analysis regressions that were performed.

6. Analysis of covariance was employed to evaluate slopes and elevations pertaining to the aging analysis regressions. Analysis of covariance findings indicated that data from testing of G and P polymers were essentially the same. Results indicated that the aging analysis data could be combined into four overall regressions, one minute constant load shear, 100 minute constant load shear, one minute constant load tensile,

and 100 minute constant load tensile, see Figures 1 to 4. Data that could not be combined into an overall regression were polymer G, phase B, in the one and 100 minute shear groups and polymer G, phase D, in the 100 minute tensile group. These regressions indicate that, with increasing age, the casebond properties are deteriorating.

7. Since the foregoing methods of analysis established a downward trend with age of the stresses required to shear or bring about tensile rupture of casebond specimens, multiple regression analysis was used to further analyze casebond data. All data pertaining to the initial specimens tested and represented by the aging regression analyses, Figures 1 to 4, were incorporated into two multiple regression analyses. The equations for the two multiple regression analyses, one casebond shear and one casebond tensile, are given in Table 6. Three axes or parameters are involved in each equation. They are Y, rupture stress in pounds per square inch; X_1, failure time in minutes; and X_2, age in months. Derived from these two equations are Charts 1 to 3. Failure times were graphed against age with each chart line caculated at a specific alert limit. The alert limits are those for storage, transportation and handling, and for booster flight. From the charts, the indication is that with increasing age the time to failure becomes critical at the alert limits represented in both shear and tensile modes.

8. As indicated in paragraph 2, test samplings from cartons are intended to represent conditions found in their corresponding as built motors; however, previous studies have indicated that significant differences exist between properties of propellant cast in motors and properties of laboratory prepared specimens. It is logically expected that aging trends will be similar and that tests of carton samplings will indicate when unexpected variations in aging stability are occurring.

TABLE 1.

CONSTANT LOAD SHEAR REGRESSION DATA, G-POLYMER

The regression model used is of the form log Y = a + b(log X) where X = time to failure and Y = shear stress.

TEST PHASE B

Lot	Age (mo)	Motor	Intercept	Slope	n	r	1 min Stress	100 min Stress
60	22	AA21311	13.0701	-7.9684	12	-.973	43.676	24.505
59	25	AA21283	12.1143	-7.3717	12	-.951	43.989	23.553
58	29	AA21209	13.8537	-8.3308	11	-.977	46.022	26.478
49	32	AA21018	14.1541	-8.6622	6	-.954	43.053	25.300
53	35	AA21063	12.4473	-7.4627	12	-.915	46.552	25.115
55	37	AA21106	13.9609	-8.5201	12	-.982	43.510	25.343
52	38	AA21021	10.4349	-6.3359	12	-.817	44.355	21.443

TEST PHASE C

Lot	Age (mo)	Motor	Intercept	Slope	n	r	1 min Stress	100 min Stress
60	42	AA21294	11.2125	-7.2152	12	-.976	35.800	18.910
59	43	AA21282	11.1911	-6.9292	12	-.966	41.216	21.205
58	46	AA21234	16.1773	-10.136	12	-.994	39.447	25.044
53	52	AA21071	14.2785	-8.4681	12	-.975	48.545	28.181
55	56	AA21117	11.5434	-7.1340	12	-.975	41.504	21.764

TEST PHASE D

Lot	Age (mo)	Motor	Intercept	Slope	n	r	1 min Stress	100 min Stress
60	68	AA21321	5.02779	-3.2491	11	-.585	35.274	17.365
59	72	AA21260	33.7135	-2.8076	11	-.896	15.878	3.0792
52	83	AA21034	11.1826	-6.9763	11	-.964	40.081	20.713
55	83	AA21125	11.9056	-7.1665	11	-.982	43.251	27.933

TABLE 2.

CONSTANT LOAD SHEAR REGRESSION DATA, P-POLYMER

The regression model used is of the form log Y = a + b(log X) where X = time to failure and Y = shear stress.

TEST PHASE B

Lot	Age (mo)	Motor	Intercept	Slope	n	r	1 min Stress	100 min Stress
64	2	AA21417	13.2989	-7.9395	12	-.960	47.319	26.493
65	5	AA21388	13.9333	-8.7228	10	-.971	39.568	23.338
63	16	AA21367	8.69682	-5.3406	12	-.950	42.505	17.945
61	21	AA21322	13.2364	-8.5704	12	-.947	35.029	20.463
62	22	AA21329	14.7193	-8.7807	12	-.950	47.460	28.091
57	28	AA21223	17.4790	-10.982	8	-.924	39.054	25.677
51	37	AA21105	14.8923	-9.0240	12	-.972	44.698	26.832
54	37	AA21137	13.6749	-8.3896	12	-.921	42.656	24.637
56	38	AA21189	14.8535	-8.9330	12	-.982	46.001	27.471

TEST PHASE C

Lot	Age (mo)	Motor	Intercept	Slope	n	r	1 min Stress	100 min Stress
67	13	AA21465	19.9178	-11.331	12	-.958	57.253	38.132
66	14	AA21462	11.8583	-6.9955	12	-.871	49.561	25.659
71	15	AA21573	11.5156	-6.6743	11	-.925	53.133	26.651
69	17	AA21522	18.7595	-11.196	11	-.979	47.375	31.399
70	19	AA21559	12.0937	-6.8629	11	-.929	57.835	29.564
68	23	AA21493	16.7583	-9.6245	11	-.995	55.107	34.151
64	40	AA21436	11.1034	-6.5490	11	-.934	49.595	24.550
61	41	AA21306	12.2860	-7.5280	12	-.955	42.860	23.248
63	45	AA21360	10.1480	-6.6027	11	-.955	34.430	17.141
65	45	AA21389	11.2362	-6.4823	11	-.921	54.120	26.597
62	46	AA21343	12.5891	-7.8257	11	-.966	40.615	22.548
57	48	AA21211	11.5756	-7.3380	12	-.977	37.800	20.181
51	60	AA21101	13.7674	-8.6801	12	-.980	38.555	29.572
54	61	AA21140	13.3955	-8.2475	11	-.984	42.067	24.068
56	65	AA21173	10.8979	-6.1682	11	-.923	58.451	27.704

TEST PHASE D

Lot	Age (mo)	Motor	Intercept	Slope	n	r	1 min Stress	100 min Stress
72	20	AA21588	16.1158	-9.6000	11	-.970	47.723	29.539
71	22	AA21573	10.7962	-6.5785	11	-.939	43.764	21.732
66	42	AA21460	14.9358	-8.9486	11	-.965	46.672	27.897
67	42	AA21466	14.1850	-8.2125	11	-.993	53.364	30.459
61	67	AA21328	9.40889	-6.3683	11	-.993	30.023	14.568
57	76	AA21201	12.8670	-7.9301	11	-.981	41.933	23.461
53	81	AA21070	12.3556	-7.6964	11	-.977	40.306	22.157
51	87	AA21086	11.1299	-6.9617	11	-.981	39.695	20.486

TABLE 3.

CONSTANT LOAD TENSILE REGRESSION DATA, G-POLYMER

The regression model used is of the form log Y = a + b(log X) where X = time to failure and Y = stress at rupture.

TEST PHASE B

Lot	Age (mo)	Motor	Intercept	Slope	n	r	1 min Stress	100 min Stress
60	26	AA21288	13.7437	-6.3986	12	-.871	98.391	50.471
59	27	AA21256	17.9335	-9.6723	11	-.936	71.450	44.385
58	28	AA21249	18.3035	-10.238	12	-.922	68.644	43.778
55	36	AA21133	22.3898	-12.392	12	-.953	64.093	44.199

TEST PHASE C

Lot	Age (mo)	Motor	Intercept	Slope	n	r	1 min Stress	100 min Stress
60	41	AA21317	22.0597	-13.145	12	-.982	47.668	33.580
58	45	AA21248	12.9768	-6.9177	12	-.737	75.143	38.617
59	45	AA21256	14.7715	-8.0956	12	-.815	66.776	37.307
53	53	AA21062	19.3238	-11.090	12	-.980	55.316	36.519
52	55	AA21036	14.3414	-8.7223	8	-.836	44.078	25.997
55	55	AA21128	20.7283	-11.669	12	-.949	59.751	40.267
52	56	AA21024	19.0532	-11.354	12	-.963	47.699	31.795

TEST PHASE D

Lot	Age (mo)	Motor	Intercept	Slope	n	r	1 min Stress	100 min Stress
60	70	AA21295	20.2605	-11.836	11	-.987	51.499	34.899
59	71	AA21283	22.8699	-13.552	11	-.991	48.703	34.672
52	82	AA21048	16.4537	-9.8669	11	-.994	46.511	29.165
55	83	AA21121	17.2319	-10.533	11	-.963	43.251	27.933

TABLE 4.

CONSTANT LOAD TENSILE REGRESSION DATA, P-POLYMER

The regression model used is of the form log Y = a + b(log X) where X = time to failure and Y = stress at rupture.

TEST PHASE B

Lot	Age (mo)	Motor	Intercept	Slope	n	r	1 min Stress	100 min Stress
56	14	AA21166	22.2074	-12.675	10	-.833	56.509	39.294
64	14	AA21420	10.7429	-5.4052	12	-.802	97.171	41.449
65	17	AA21393	18.5944	-10.801	12	-.927	52.661	34.382
63	20	AA21360	18.4521	-10.654	12	-.944	53.947	35.014
62	22	AA21337	19.8863	-11.258	12	-.953	58.393	33.792
61	24	AA21305	16.3522	-9.1211	12	-.821	62.058	37.457
54	35	AA21136	27.0012	-15.383	12	-.955	56.925	42.197
51	39	AA21094	23.0135	-12.893	12	-.852	61.006	42.682

TEST PHASE C

Lot	Age (mo)	Motor	Intercept	Slope	n	r	1 min Stress	100 min Stress
69	14	AA21547	16.6397	-8.9140	11	-.734	73.569	43.886
67	16	AA21448	18.0061	-10.066	12	-.979	61.499	38.920
71	16	AA21581	12.6581	-6.1827	11	-.869	111.51	52.947
66	17	AA21441	18.6003	-10.044	12	-.931	71.100	44.952
70	23	AA21531	12.7410	-6.1702	10	-.601	116.13	55.055
68	30	AA21459	14.6537	-8.5349	11	-.857	52.108	30.379
63	39	AA21379	13.5730	-0.4669	11	-.083	------	------
61	40	AA21326	25.1976	-14.309	12	-.928	57.679	41.806
64	42	AA21417	22.9380	-12.465	11	-.962	69.216	47.836
65	44	AA21404	17.0212	-9.8910	10	-.929	54.335	33.012
62	47	AA21329	18.3478	-9.5702	11	-.954	82.637	51.073
57	50	AA21194	24.6502	-13.894	12	-.925	59.456	42.682
51	60	AA21084	23.0903	-13.139	12	-.939	57.191	40.283
54	61	AA21148	24.3077	-14.062	11	-.957	53.533	38.583
56	64	AA21184	15.9249	-8.6167	11	-.898	70.492	41.308

TEST PHASE D

Lot	Age (mo)	Motor	Intercept	Slope	n	r	1 min Stress	100 min Stress
67	38	AA21487	14.6186	-7.3336	11	-.875	98.481	52.558
66	46	AA21442	19.2808	-10.440	11	-.912	70.288	45.217
61	69	AA21310	17.0889	-10.125	11	-.932	48.732	30.923
57	76	AA21215	20.2346	-12.234	11	-.942	45.080	30.939
53	82	AA21057	16.7398	-9.8964	11	-.962	49.148	30.861
51	85	AA21098	13.2229	-7.9487	11	-.910	46.083	25.818

TABLE 5. ONE MINUTE AND 100 MINUTE DATA PERTAINING TO AGING ANALYSIS REGRESSIONS

	Polymer	Test Phase	Stress at Failure Intercept	Slope	S_e	n	t	Significance
One	G	B	43.027	0.0480	1.593	6	0.39	NS
Minute	G	C	18.941	0.4678	4.263	5	1.32	NS
Constant	P	B	43.441	0.0094	3.525	8	0.10	NS
Load	P	C	56.190	-0.2183	7.647	14	1.85	NS
Shear	P	D	50.982	-0.1473	6.115	8	1.69	NS
100	G	B	22.675	0.0791	0.959	6	1.07	NS
Minute	G	C	9.723	0.2782	3.710	5	0.90	NS
Constant	P	B	23.381	0.0726	3.333	8	0.83	NS
Load	P	C	33.245	-0.1671	4.856	14	2.23	S
Shear	P	D	29.754	-0.1092	4.804	8	1.60	NS
One	G	B	89.966	-0.7221	1.481	3	3.40	NS
Minute	G	C	31.775	0.4065	6.440	4	0.76	NS
Constant	G	D	82.136	-0.4529	1.834	4	2.97	NS
Load	P	B	51.015	0.1901	2.652	4	0.98	NS
Tensile	P	C	70.699	-0.1847	9.713	9	0.87	NS
	P	D	96.123	-0.6181	4.683	5	4.11	S
100	G	B	43.895	0.0074	0.437	3	0.12	NS
Minute	G	C	27.843	0.1502	4.353	4	0.42	NS
Constant	G	D	71.536	-0.5212	0.385	4	16.30	S
Load	P	B	27.519	0.4288	1.556	4	3.79	NS
Tensile	P	C	43.257	-0.0270	5.717	9	0.22	NS
	P	D	64.881	-0.4487	2.484	5	5.62	S

Note: S is significant and NS is not significant.

TABLE 6. MULTIPLE REGRESSION EQUATIONS AND SUPPORTING DATA

The regression model used is of the form $\log Y = a + b_1 \log X_1 + b_2 X_2$ where Y = stress in psi, X_1 = failure time in minutes, and X_2 = age in months.

Constant Load Shear equation: $\log Y = 1.695 - 0.1037 \log X_1 - 0.00136X_2$

Constant Load Tensile equation: $\log Y = 1.809 - 0.07341 \log X_1 - 0.00173X_2$

Supporting Regression Data

	Constant Load Shear	Constant Load Tensile
N	418	319
$\sum (X_2)^2$	954221	910732
$\sum X_2$	17679	15560
S_e	0.072434	0.059073
r^2	0.77511	0.80509
K	1.724	1.737

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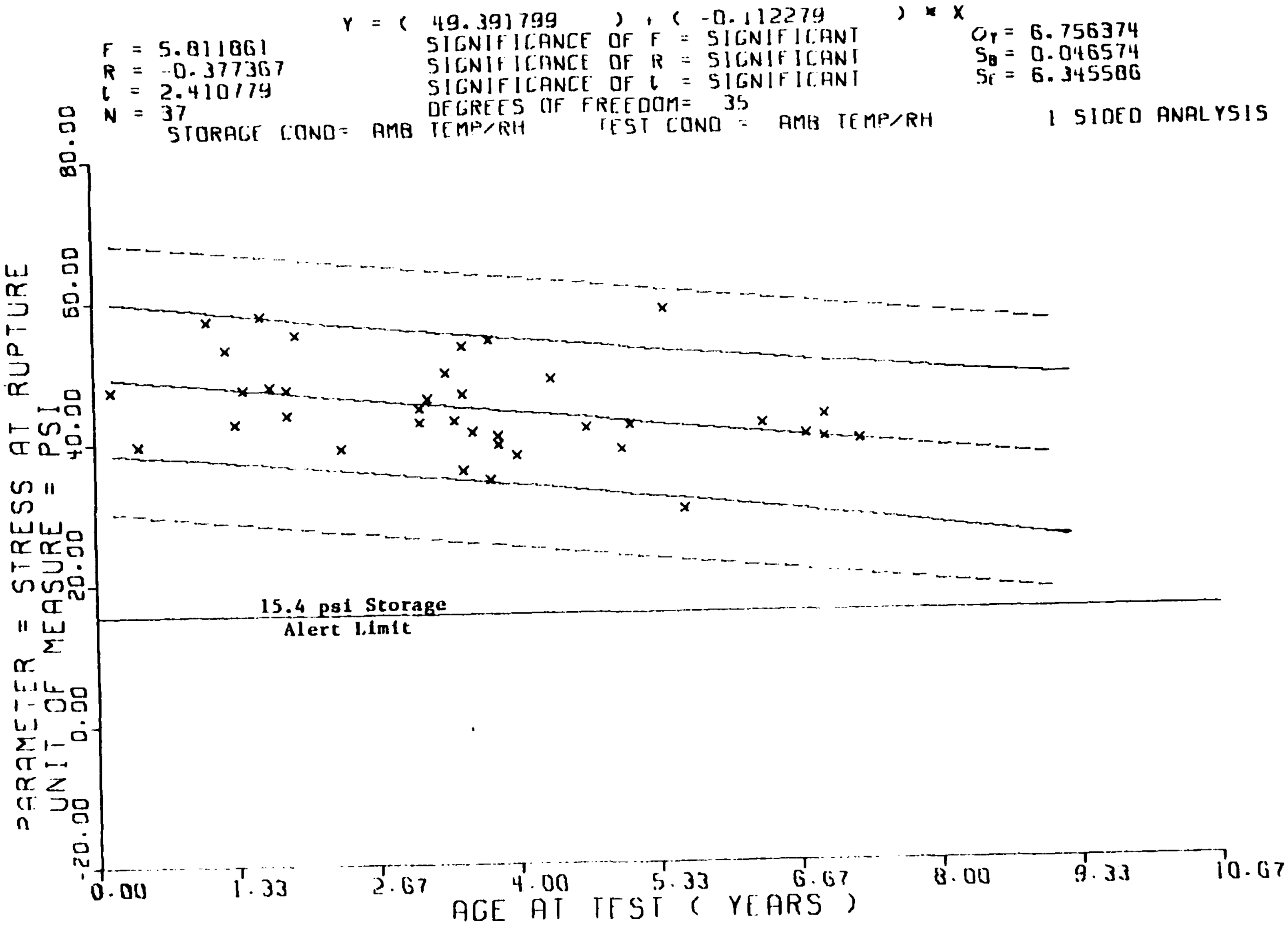
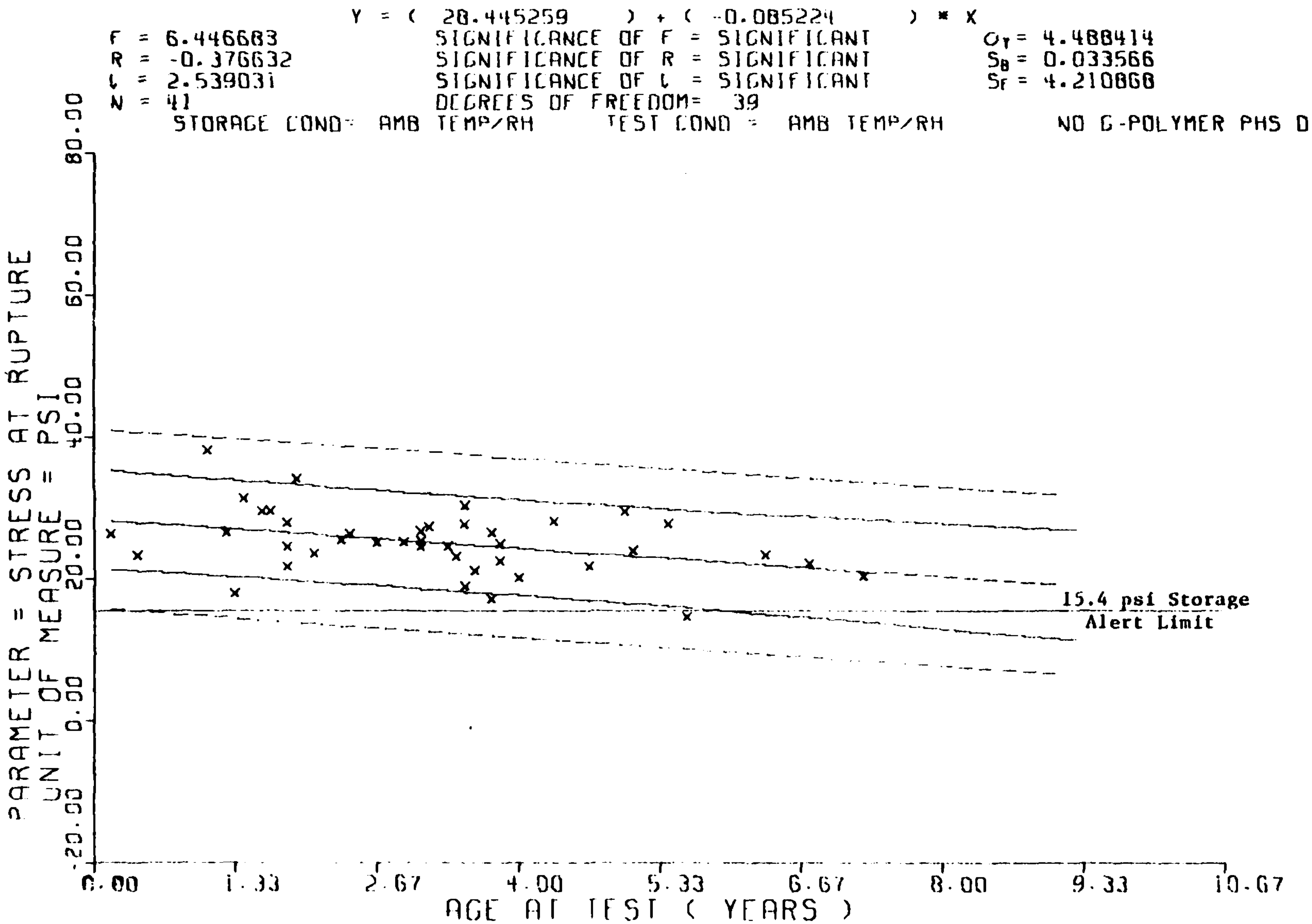


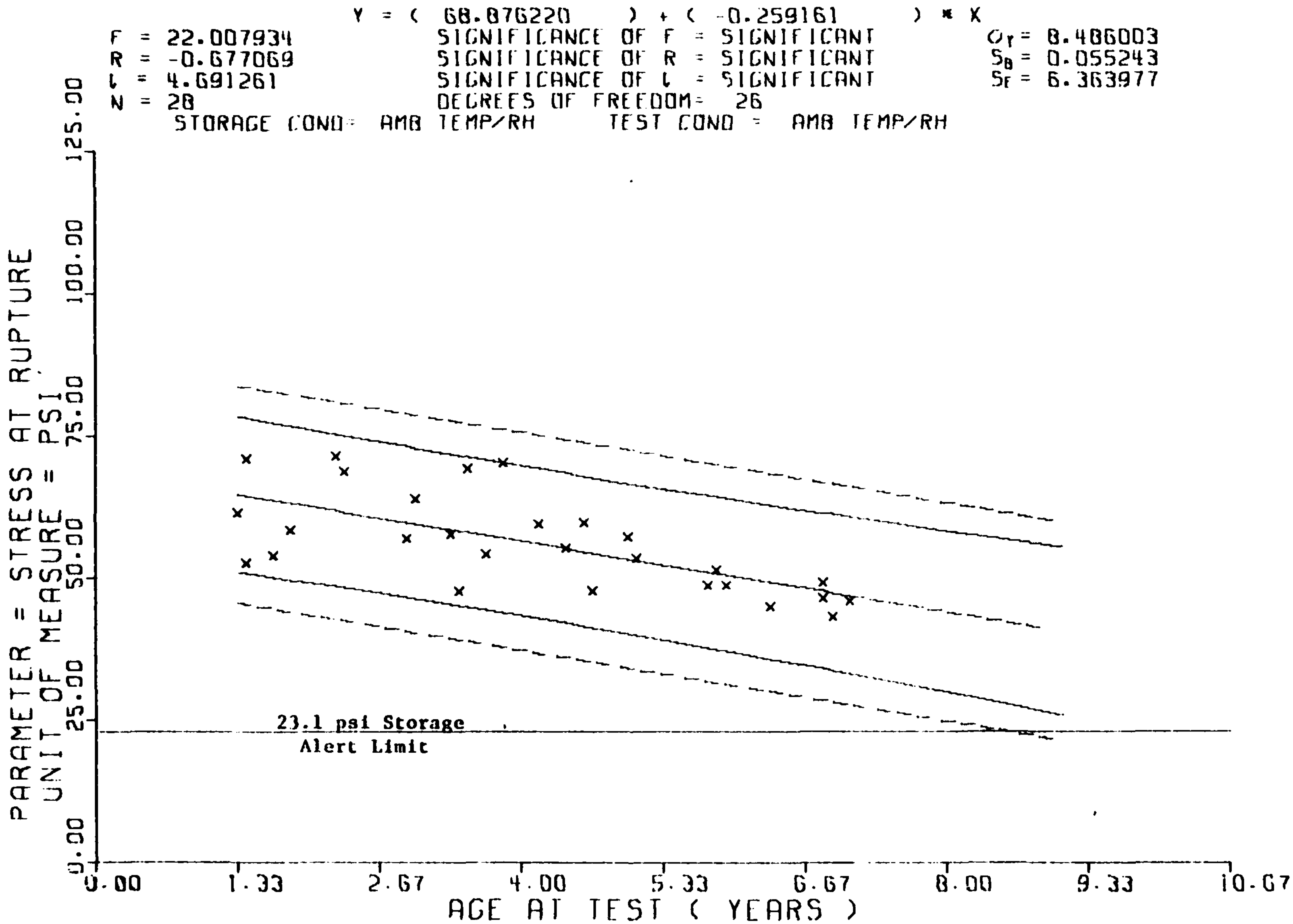
CONSTANT LOAD SHEAR. ALL PHASES AND POLYMERS EXCEPT G-POLYMER PHASE B. ONE MIN

FIGURE 1.



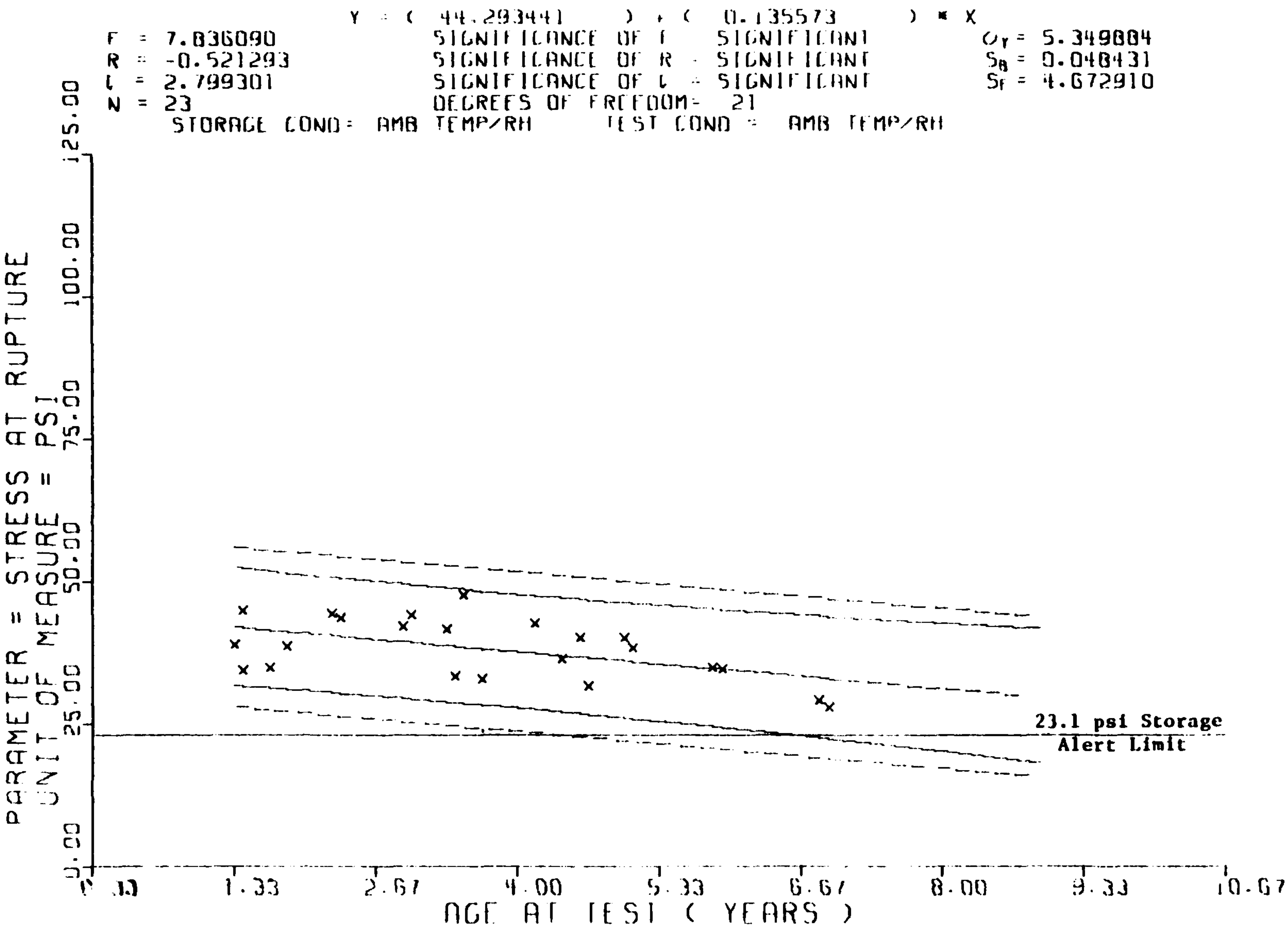
CONSTANT LOAD SHEAR. ALL PHASES AND POLYMERS EXCEPT G-POLYMER PHASE B. 100 MIN

FIGURE 2.



CONSTANT LOAD TENSILE. ALL TEST GROUPS. ONE MINUTE DATA

FIGURE 3.



CONSTANT LOAD TENSILE, ALL TEST GROUPS EXCEPT G-POLYMER PHASE D, 100 MINUTE DATA

FIGURE 4.

CHART 1. Casebond Failure During Transportation and Handling. Testing indicates a five percent probability of failure if a psi alert limit load is sustained for the time corresponding to its respective age.

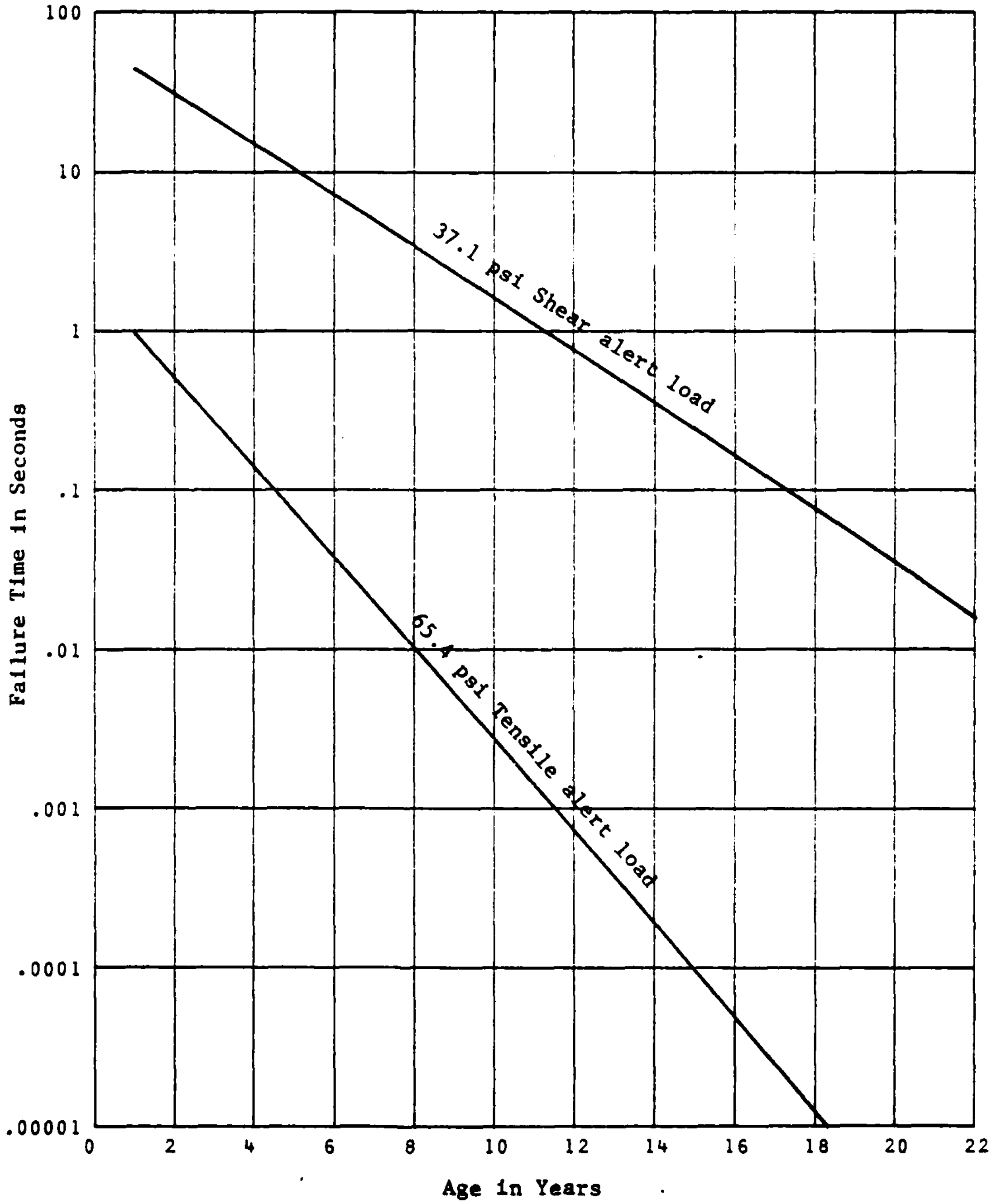


CHART 2. Casebond Failure During Storage. Testing indicates a five percent probability of failure if a psi alert limit load is sustained for the time corresponding to its respective age.

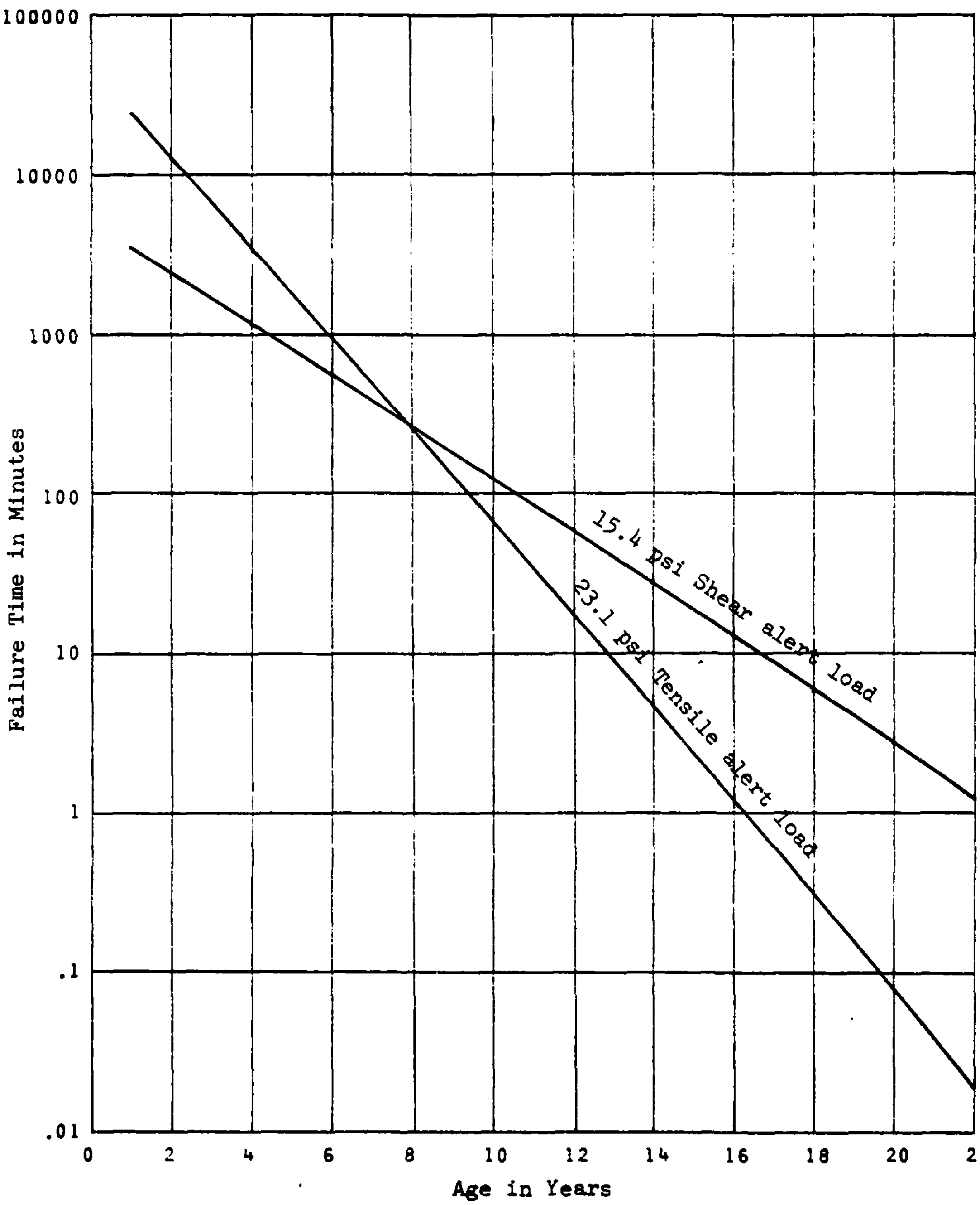


CHART 3. Casebond Failure During Booster Flight. Testing indicates a five percent probability of failure if a psi alert limit load is sustained for the time corresponding to its respective age.